NASA Administrator
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My dear friend Gene Shoemaker had a very special dream.

He wanted to go to the moon.

He devoted much of his career to training astronauts so they could make this trip successfully. He was one of the world's foremost experts in crater and planetary science. And as you all know, he -- along with his wife -- even helped discover a comet . . . it's named after him.

But his dream . . . was to go to the moon.

Today, a small portion of his ashes are aboard the Lunar Prospector that successfully launched from Cape Canaveral last night.

His dream is coming true . . .

. . . so is NASA's.

Because Lunar Prospector symbolizes where NASA is going and what we dream about -- and I'm not just talking about going back to the moon for the first time in 25 years.

Last night, the Lunar Prospector launched on a Lockheed Martin Athena-2 rocket -- a brand new rocket . . . the first time it worked. It carries half the payload at half the cost of existing rockets . . . showing that we don't need big, expensive launch vehicles.

The entire life cycle of the Lunar Prospector mission was only 63 million dollars -- our lowest cost planetary mission. We launched it about three years after we began development. And it's going to provide wonderful science. (I'm assuming we're going to get to the moon by Sunday.)

Just think about this success story and compare it to where we were when we met two years ago in San Antonio.

Back then, not only was our country in the midst of a budget crisis . . . but NASA was in the midst of a major revolution.

We were being challenged to do more with less. To plan much better. To focus on our customers -- the American public. To concentrate on scientific output . . . not financial input. And to do the hard and exciting things that people expect from NASA.

I don't have to tell you that it hasn't always been this way. In the early 1990's, we -- especially the Space Science program

-- were in deep trouble:

Hubble was a mess; an icon for failure in U.S. science and technology. The Advanced X-Ray Astrophysics Facility (AXAF) development had been broken into two missions and the second half canceled.

The Galileo mission had a broken antenna, Mars Observer was on its way to a major disaster.

No new planetary or astrophysical programs were on the books . . . and those that were planned were unrealistically expensive and had undeveloped technologies that they were relying on.

At that time, Space Science missions cost half- to multiple-billion dollars, weighed thousands of kilograms, took almost a decade to build and almost always overran their budget by large amounts.

At this cost, there was almost no hope that any other missions would be built in the near future.

We had an uphill battle in front of us. We were a troubled space agency.

Two years ago in San Antonio, a lot of people asked: How do you "implement" a plan to do great science in a time of declining budgets? They questioned whether it could even be done?

Today, I'm here to say: "Yes. It can be done. And together, we're doing it."

Hubble is fixed and has become a symbol for success and inspiration for U.S. science and technology; one of the most remarkable turn-arounds in the history of the agency. Proof of that comes with every image . . . whether it's a picture of two galaxies colliding . . . or the image of magnificent interstellar clouds caught in the act of forming new stars.

The AXAF imaging mission is getting ready to launch and the second half -- the spectroscopy mission -- has been resurrected through cooperation with the Japanese.

Galileo's mission to Jupiter was saved through shear innovation and hard work by the wonderful engineers at the Jet Propulsion Laboratory (JPL). . . and we have started a successful Mars robotic exploration program that has already electrified the world.

And we are now set to fulfill the two decade-old dream of space astronomers; completing the fleet of Great Observatories.

Two years ago, I promised you the Space InfraRed Telescope Facility (SIRTF) and the Stratospheric Observatory for InfraRed Astronomy (SOFIA). Today, you have them both.

You not only have the dream of the Great Observatories fulfilled, but you also have a growing fleet of smaller, complimentary spacecraft . . . sixteen new observatories are already flying or under development.

Alone, this progress we have made over the past two years is impressive. But when you couple that progress with some of the discoveries that are -- in part -- the result of this progress . . . it is truly extraordinary.

Recent discoveries:

In so many areas, we have made amazing discoveries. Just think about the pictures of the Red Planet in the news magazines or the countless times an image from Hubble appeared on the front page of a major newspaper.

But allow me to share with you some of the discoveries we've made in just one area -- Origins. Incidentally, we talked about the Origins program in San Antonio. Two years and a White House symposium with the Vice President later . . . the President has proposed an Origins initiative . . . and Congress has accepted it.

Here's what we've found:

First -- The Hubble Space Telescope directly detected a planet around a star.

Just a few years ago, the Hubble Space Telescope took a picture of a Jupiter-sized planet around another star . . . about 40 astronomical units away.

Evidence that the planet forming process may be common around young stars.

The Hubble Space Telescope also looked at the Orion Nebula and found newborn stars with proto-planetary disks of gas and dust . . . they look just like what we think our own proto-planetary disks might have looked like before planets formed in our solar system.

Mars -- 3.8 billion years ago, Earth and Mars were very much alike.

They were warm. They had volcanic activity. They were wet. They had condensed environments with dense atmospheres of carbon dioxide and protective magnetic fields.

The Mars Pathfinder returned strong evidence that there was flowing water.

The Mars Global Surveyor detected a remnant magnetic field on Mars. So we think it probably had a protective shield from cosmic radiation early in its evolution.

Mars Rock . . . ALH84001

We think we might have found a fossilized sample of life from that's about 3.6 billion years old . . . that's a few 100 million years after we think water appeared on Mars . . . and about 100 million years before Earth's earliest fossil microbe.

Europa -- ocean

On Europa, one of Jupiter's moons, we think we may have found a liquid water ocean underneath a thick ice crust.

Because Jupiter is so big, and this moon rotates around it, the gravitational pulling could heat up the core of Europa. So we might have a condition where there is a liquid or slush ocean underneath all the ice.

We have found that the instant life could exist . . . it did.

3.9 billion years ago, the Earth cooled down to the point where we had liquid water on the surface. We found a fossil carbon in Greenland a few years ago, that was 3.85 billion years-old.

Think about it. Within just 70 million years . . . of a 4.6 billion year history . . . this is milli-seconds -- a blink of the eye -- on the geological time scale . . . life developed on Earth.

And we have found that life exists in extreme conditions.

Life exists in boiling water under crushing pressures. Life exists in near-freezing lakes in the Arctic and Antarctic. Life exists in acid pools near volcanic geysers. And miles below the Earth's surface, there is life eating away at rock and belching gas.

We now find life on Earth where ever we find the tiniest amount of moisture with some source of energy, a transport mechanism, and protection from lethal space radiation.

So here are the conclusions:

One is led to believe that planet forming may be common. Many stars -- we believe -- may have planets circling them. Life exists in extreme conditions. Single-cell life arises early and easily. And maybe, life might not be unique to Earth.

Soon we will have further advances -- like the Next Generation Space Telescope to replace the Hubble . . . a new breed of space observatories, space interferometers, that will search for and study planets around other stars with unprecedented spatial resolution. And with these advances we will finally begin to obtain a deeper understanding of: who we are . . . where we come from . . . and where we might be going.

What a time to be part of the space program. What an unbelievable time to be alive.

And it seems like every week we're finding something new.

Of course, there's a good reason for that -- something a lot of people in this room can take credit for. After all, the developments and the discoveries did not happen overnight. And they certainly did not happen by chance.

Restructuring:

Two years ago, I told you we needed to do things in an entirely new way.

I said, we can no longer manage programs according to object orientation. I said we could not afford -- nor was it right -- to be driven by big programs. Our customers -- the American taxpayers -- deserved more.

I said, NASA must be organized and dedicated to answering fundamental scientific questions -- questions outlined in our strategic plan.

Two of those fundamental scientific questions in our strategic plan relate directly to space science:

First: How did the Universe, galaxies, stars and planets form and evolve? How can our exploration of the Universe and our solar system revolutionize our understanding of physics, chemistry and biology?

And secondly: Does life in any form, however simple or complex, carbon-based or other, exist elsewhere than on planet Earth? Are there Earth-like planets beyond our solar system?

The Space Science enterprise will also help answer questions like how we can use the knowledge we gain about the Sun and Earth and other planetary bodies to improve our lives here on Earth . . . and what cutting edge technologies must we develop to enable our research agenda.

So Wes Huntress and his team got together with many of you -- because we couldn't do this alone . . . and you went to work.

And what a job you did.

You met the challenge to reduce these fundamental scientific questions into an inspirational statement of what Space Science wants to do and where we want to go.

And just as important -- that statement can be understood by anyone . . . especially those who provide the funding for the program.

This was an unbelievable undertaking and people have been very complimentary.

By the way, if you want to read NASA's strategic plan . . . or the roadmap for the Office of Space Science (or NASA's other enterprises: Earth Science, Aeronautics and Access to Space, and Human Exploration and Development of Space), you can access them through our web site. WWW.NASA.GOV

We now have four simple points that instantly articulate the mission -- our roadmap -- of Space Science.

We want:

€ to Solve Mysteries of the Universe
€ to Explore the Solar System
€ to Discover Planets Around Other Stars
€ and to Search for Life Beyond Earth

All of you did a great job

But we must remember. . . this plan is not an end. It is a starting point.

Our goal is -- and this plan requires us -- to push the envelope of technology.

We need to be building spacecraft out of chip sets, not out of large numbers of 10 kg black boxes connected with miles of wire harness.

We need to be able to build them on the table top with a few people instead of in high bay areas with hundreds of people.

We need to be able to make the spacecraft bus of the future in the same way we make personal computers today so that the spacecraft becomes a service function to the mission, just like launch services, and the means to an end; not the end in itself as it is most often today. Too often people are concentrating on winning big spacecraft contracts so they can build big empires . . . so they get big profits . . . instead of delivering science to the American people.

We will no longer call them spacecraft, but sciencecraft.

And we need to be able to operate them just as we do PC's today -- with standard operating system software including a mission-specific layer . . . and just a few people using workstations and not hundreds of people using mainframes with custom software for each mission. We proved we could do this with the Mars Pathfinder. When we sent Viking to Mars twenty years ago, we had a thousand people in operations. On Pathfinder, we had 50.

We have a lot to do -- and later this afternoon, Wes Huntress will discuss the strategic plan in more detail. But I'd like to touch on a few things to get you thinking . . . and imagining . . . and, yes, dreaming a little . . . just like Gene Shoemaker.

What the Future holds is a Balanced program:

This wonderful strategic plan for space science provides a balanced program for the future - it responds to solving the mysteries of the Universe, exploring the solar system, discovering planets around other stars, and searching for life beyond Earth.

€ TO SOLVE MYSTERIES OF THE UNIVERSE

Astronomers are really just scientists at work in the greatest laboratory of all -- the Universe. You investigate the birth of stars and galaxies, discover possible oceans on distant moons of Jupiter, probe the structure of the Sun, and reveal the secrets of black holes.

And solving the mysteries of the Universe is one of the great public challenges of NASA and the Office of Space Science. It challenges us all to think more creatively.

But we have more mysteries to solve.

Gamma ray bursts:

Gamma ray bursts have been one of the premier Mysteries of the Universe for over 30 years.

We learned a lot this year with the first detections of gamma ray burst afterglows in X-Ray and optical light. Now we know what questions to ask with our next generation of missions.

Can we see relativistic signatures from the gamma rays? Can we detect the prompt X-rays from the gamma ray burst? Can we see the optical and radio light from all gamma ray bursts?

We will need greater sensitivity - at least two orders of magnitude - and more precise positions - at least a factor of 10 better (from arc minutes to arc seconds) - and rapid response - not hours, but seconds.

We must go from our phenomenological understanding to exploring new physics. The technological means to do this are in-hand . . . and can be done with the NASA MIDEX class of mission . . . and hopefully, for just tens of millions of dollars. Peer review will determine it. And I'm hoping that someone in this room will be inspired to send a proposal and finally nail down these gamma ray bursts.

Active galaxies:

The mystery of active galaxies has been with us since the discovery of the first quasar 35 years ago. We think they are powered by massive black holes at the center of a galaxy.

But what clues do black holes hold for understanding the physics that has controlled our universe, since the origin of the whole shebang? What is the new physics involved in creating high energy gamma rays in what may be the largest particle accelerators in the Universe?

We need X-Ray and gamma ray observatories which can peer through the obstructions of the accretion disk and the surrounding corona, peer directly into the heart of the black hole. And do it over the broadest possible energy range . . . to maybe give us a hint of the environment at the boundary of a black hole.

The next generation X-Ray mission CONSTELLATION will help solve the mystery of what powers active galaxies. But first we must solve the major technology challenge. That challenge is lightweight, high resolution mirrors . . . about an order of magnitude lighter than we've ever built, the Astro-E.

We need a much lighter system to achieve the huge increase in collecting area to allow high through-put spectroscopy without hurting the launch system.

I'll share with you an example.

If we achieve an order of magnitude reduction in weight, we will reduce the launch cost with existing launch technologies from $2.4 billion to $240 million. That is why we're doing this.

Also at NASA, we're trying to develop new launch vehicles that will cut the cost of launch. And if we're successful then, perhaps we could reduce the cost of this mission by another $200 million. So what could have been a $2.5 billion mission, may be able to be done for a quarter to a half billion dollars.

But it's up to you. We will not have any money for a new start until you convince us that you solved the technological challenges.

And to study the gamma ray beams from nature's accelerators, we need a team effort -- not just the astrophysicists but particle physicists and high energy physicists as well.

GLAST -- which is the replacement for the gamma ray observatory -- is a particle physics experiment in space, with wide-eyed vision . . . watching those rare high energy gamma ray outbursts which make the Universe twinkle and change and evolve at the highest energies. And it does this by imaging half the sky at a time by measuring the energy distribution of collected gamma rays.

The technology for GLAST is already here -- it's just a matter of execution . . . at acceptable and minimum cost. This is not a high cost mission. And again, we're expecting someone to grab the bull by the horns and demonstrate this can be done for cost.

Big Bang:

We all remain intrigued about the appearance of structure in the Universe: the Big Bang appeared so smooth to the Cosmic Background Explorer (COBE), so unperturbed, but we see concentrations of galaxies interspersed with enormous voids, stretching tens of millions of light years.

It makes us ask: How did galaxies and the first stars form? How did they collect into vast clusters?

In about a decade, the Next Generation Space Telescope (NGST) will be our foremost tool for studying the very earliest stars and galaxies.

Building upon the foundation of the Hubble Space Telescope and soon SIRTF -- but a great leap beyond both -- NGST will investigate the first bursts of stellar creation and the concentration of matter into galaxies . . . the building blocks of the cosmos.

And, in collaboration with our partners in the European Space Agency . . . scientists will use the Far-InfraRed Space Telescope to study the birth of the heavy elements. We hope to study how the first stars enriched the young Universe with the dusty matter necessary for planets and, perhaps, life.

However, just as NGST will reveal the details of the origin of the first galaxies . . . it is also critical to map out the fine-scale distribution of the ripples in the radiation created within the Big Bang.

COBE showed us how smooth the early Universe was and future missions -- the Microwave Anisotropy Probe (MAP) and Planck-- will hopefully show us how corrugated it was. And they will measure the effects of gravity during this long-ago time . . . and we may finally learn the fate of the Universe. The way we're going to pick up these cosmic ripples is by developing the technology to go to yet higher spatial resolution.

Now let me shift gears -- exploring the solar system.

€ TO EXPLORE THE SOLAR SYSTEM

Our goal is to establish a virtual presence throughout the solar system, where we might determine the history and study the current environment.

In effect, we will complete the first census of our solar system before the end of the next decade.

What is the pre-biological history and biological potential of Mars and other bodies in the solar system? Does a liquid water ocean exist today on Europa and is there evidence for organic or biological processes there? What are the processes that underlie the diversity of solar system objects, notably the small bodies, such as the Moon and

Pluto?

The missions:

A Europa Orbiter will tell us whether or not there is a global ocean beneath that fractured, icy crust, and enable us to pick out the most promising landing sites for a future mission aimed at probing beneath the surface.

The Pluto/Kuiper Express mission will investigate Pluto and bodies in the Kuiper belt and determine the potential of the Kuiper belt as a source of water and other volatile materials in the major planets.

The Mars Surveyor Program will conduct detailed surface and orbital studies to expand our knowledge of Mars and enable selection of samples for return to Earth on sample-return missions starting in 2005. And it is my hope and expectation that we will do this with the French. And if we get an opportunity to use their Ariane 5 launch vehicle . . . we will not have one sample return, but two. Discussions are already underway.

The low-cost missions of the Discovery Program will continue to complement the outer planet and Mars missions . . .

with Lunar Prospector;

the Stardust mission to collect samples of a comet and interstellar dust;

the Genesis mission to collect a sample of the solar wind ;

and the Comet Nucleus Tour (CONTOUR) mission to the comets.

Along with Cassini and the continuing Galileo Europa mission, these spacecraft will revolutionize our understanding of our own solar system.

Just think. In the 1980's we launched two -- count them, two -- solar system exploration missions . . . Magellan and Galileo. During the 15 months beginning in October 1997 we will launch seven spacecraft -- an average of one every 10 weeks.

Cassini, Lunar Prospector, Deep Space 1, Mars 98 Orbiter, Mars 98 Lander, Deep Space 2 and Stardust.

And I might say that the last six missions are less than half the price of Cassini. You are doing an outstanding job.

The technology -- if we're going to send spacecraft to Pluto and the furthest reaches of the solar system, they will need revolutionary propulsion and power systems. They will need ultra-low power consumption electronics which will enable the communications industry here on Earth. They will also need to be a thinking, intelligent spacecraft. They might be too far away for operational commands to come from Mission Control -- to communicate will be much more difficult because of the tremendous dilution of the signal over the large and vast distances of space.

This means radical change in operations and communications.

The Sun:

At the center of the Solar System is a variable star whose hot outer envelope expands at supersonic speed to fill the solar system with hot solar plasma out to at least twice the distance to the outermost planet, Pluto.

How and why does the Sun vary? How does the Sun impact planetary environments? How does the Sun interact with the interstellar medium? How do we most effectively use our Solar System as a laboratory for studying how stars work, the interactions between a star and its surrounding system, and fundamental plasma physics processes that might help understand the process of the energy generation here on our own planet.

Solar Probe will make the first fly-by close to a star to enable close-up imaging of the solar surface and in situ sampling of a stellar corona.

We now believe that we know how to design and construct a spacecraft that can survive in the intense thermal environment within three solar radii of the Sun's surface. Other Smallsat and microsat missions will perform a systematic study of the Sun-Earth system.

For example . . . microsat technology, miniaturized instruments, and an innovative laser communication system can enable flight of a mission with dozens of low cost microsats. They could be launched on a single booster to simultaneously probe both single and small scale phenomena in a highly variable planetary space environment.

€ TO DISCOVER PLANETS AROUND OTHER STARS

I talked earlier about the discoveries of extra solar planets and proto-planetary disks that resemble what we think our own might have looked like.
But we still have a long way to go.

These results might be planets, but might also be "failed stars." Together with the National Science Foundation, we must search for planets with much lower masses than that which can be detected with today's techniques. We must look for planets more similar to Earth.

We are going to challenge the community to execute the technology they developed and detect indirectly, from the ground, the gravitational effects of planets 10 to 100 times less massive than those found so far.

First, the Keck interferometer will detect the presence of planets with masses as small as that of Neptune, And not long after, we will launch the Space Interferometry Mission (SIM), which we hope will detect the presence of planets down to a few times that of Earth's mass.

This is not going to be easy, as images of planetary systems are "polluted," by a factor of many millions, by the intense light of the star which warms these far-off worlds. But I'm confident we can do it.

Then, using techniques learned from SIM, we will build the Terrestrial Planet Finder, an interferometer in space at least the size of a football field. The Planet Finder will produce images of planetary systems and will analyze the faint light from planets and search for the fingerprints of biological activity.

The NGST Project is now challenging this country's technological community to design and to develop a deployable telescope perhaps as large as 8 meters -- more than three times the size of Hubble -- in diameter. And the surface accuracy will be fine enough to operate at wavelengths as short as 1/2 micrometer . . . and at the operative temperatures of just above absolute zero.

This is not easy. More about that later. By the way we have two teams who believe that they can build this with a specific mass of less than Hubble by a factor of twelve . . . and a total life cycle cost of a factor of 6 less than Hubble.

We are approaching the goal I set two years ago. And the technology will revolutionize not just astronomy . . . but it will revolutionize the technology that helps form the economic base of America.

To achieve even greater resolution, we are challenging the scientific community to develop Interferometry in space . . . first with SIM early in the next decade . . . and then with Terrestrial Planet Finder a decade from now.

This is going to require systems capable of picometers of precision. . . and this over a baseline of 10s of meters to 1000s of meters. This is a also a tough thing to do.

With a successful SIM mission, much of the technology will be ready for Planet Finder, but one key element will be necessary -- nulling: the capability to cancel the central starlight to a part of 100,000 to 10 million or better and permitting the light from the planet to be analyzed.

When these missions are launched . . . then the scientific community will have truly set NASA on the course to answer the question we have all asked: "Are we alone?"

€ AND TO SEARCH FOR LIFE BEYOND EARTH

Right now, for where we have found life, we have a sample of one. Planet Earth.

But fortunately, in part because of some of the spacecraft I described, we are not bound to this planet. With space exploration and modern instrumentation, the tools to solve the mystery of life might be at hand.

The innovative research and recent discoveries from space exploration may find that life is a natural consequence of planetary and chemical evolution, common in the Universe.

How does biology fit into our understanding of the universe?

To help meet this challenge, we are introducing a new unifying approach to biology within the Agency... Astrobiology.

Our first request for proposals has brought in an incredible response. I believe there are about 70 organizations that intend to propose.

Astrobiology is the study of the chemistry, physics and adaptations that influence the origin, evolution and destiny of life. We intend to raise the consciousness of biology within the NASA by relating relevant biological questions to our missions and Programs.

And that's a real challenge. For us. And also for you.

Our contemporary ideas of life are changing. We are experienced in measuring the inorganic . . . we still need to become experts in measuring the organic -- experts in the signs of life . . . able to detect even the faintest traces of life.

Here's an example -- when Galileo flew by Earth, an experiment was done to detect life on our own planet only with the instruments on Galileo.

The data revealed that Earth has oxygen in the atmosphere . . . green pigment on the land surface . . . and methane out of equilibrium.

But what does all of this mean?

It means that life on Earth is actually very subtle. At night, you can see lights. But in the daytime, virtually no visible signs of intelligent life were detected.

Now expand this distance a billion times, from 100,000 miles to 100 light-years. That's a challenge.

Ozone, water, and carbon dioxide can be detected with a very large interferometer, but to detect the biologically important methane would require telescopes 100 times larger in area than we think we can build ten years from now.

Detection of nitrous oxides would need an even larger telescope.

So we are left with the question: what other biological fingerprints must we look for in the search for life?

In the case of Galileo flyby of the Earth, we knew the solution . . . we cribbed the answer!

Life could be ubiquitous, but life on Earth could be cosmologically unique.

We just don't need to know where to look . . . We need to know what to look for.

Why should we expect oxygenic photosynthesis by green plants to be universal? Maybe a purplish rhodopsin dominates. Maybe photosynthesis is rare. Our own Earth did not have an oxygen atmosphere for the first 2 billion years. A Galileo fly-by two billion years ago would have concluded Earth was lifeless . . . but at the time, Earth was rich in microbial life.

We need to develop understanding of potential biogeochemical cycles to build reasonable models of extraterrestrial biospheres.

We need a catalogue of detectable "characteristics" of extraterrestrial biospheres and a catalogue of fingerprints for life. The characteristic combinations of chemical species must be defined and the limits of detection met before we design spacecraft like Planet Finder.

Let me stop for a moment to run an experiment.

How many of you have gone through the university system with formal training in the biological sciences? Raise your hands, proudly.

(Of the 1500 people in the audience, two or three raised their hands.)

Is this the group that is going to search for life?

This is a serious problem.

The leadership of NASA . . . the leadership of the scientific community . . . is saying we want to develop platforms that cost hundreds of millions of dollars . . . yet we don't have a biologist in the house to help us define what the requirements for the science might be.

Think about that.

That's why we set up a series of biology seminars at NASA Headquarters for our scientists and engineers. We're on a hiring freeze . . . but NASA is hiring biologists. Because biology and biological evolution has passed us by.

In this country, too often, we think as biology only in terms of medical care. And we don't think about the implication of biology on the fundamental science we do . . . or the tools we're trying to build.

We really need to think and talk about this -- in this organization and in the community at large. It is shameful for us to have an origins program for billions of dollars and all we have is chemists and physicists.

Now don't get me wrong. Physical scientists are good. But I think I made my point.

The Atmospheric chemists, planetologists, and geomicrobiologists need to build a knowledge base, do the experiments and modeling. And in a little over a decade, planets orbiting other stars will be imaged and the question will be "Is there life?"

Will we be ready to answer that question?

The scientific goal is not only discovering if there is life elsewhere . . . but what is the range in the universe of biological possibilities and living systems?
We know that life can be tenacious and robust, and can transform an entire planet, we do not know the range of possibilities. Someday we will need that information for planetary engineering.

Besides people who are technically trained, the public is inspired and stimulated by the biological sciences. New computers that use biological elements and run on microcircuits, like our brain, could be used in future exploration aboard very advanced spacecraft.

If we're successful building this biological computer, the energy consumption will be orders of magnitude less than that of silicon.

Adaptive strategies that change as the mission proceeds will need not just Œsmart' spacecraft, but developmental elements that build on knowledge obtained during the mission.

Explorers of the future will not be mission specialists they will be physicists, chemists -- and biologists -- interacting with your robots.

We are about to venture into an experiment to form a Œvirtual' Astrobiology Institute that will bring the necessary physicists, chemists, biologists and cosmologists together electronically to develop the detailed questions of the future.

Is RNA a universal molecule involved in every life form? How small can life be? Is chemical chirality necessary? What planetary niches are forbidden domains where no life can exist? What is the biodiversity of life in the universe? What are the universal signs of life?

These are the kinds of questions all of us need to be asking. And these are the kind of questions that we will be asking at our new virtual Astrobiology Institute.

The Nation's response to the Pathfinder and the Hubble success was a hallmark of its thirst to "find out." We now have to go beyond to the dreams of our science fiction writers, to show that nature is even more remarkable than our imaginations.

Where we will be by 2020

And that leads me, finally, to where I think we will be in the next 25 years.

In a few years, we will transition to the New Millennium at the opening of what will be the Century of Space Travel, just as this past century has been the Century of Air Travel.

NASA is ready for this.

And the public is ready for this.

The American people have shown tremendous excitement for all that we have been doing recently; we seem to have struck chord with our plans for exploring Mars and the solar system, and with our plans to search for planets around other stars, and to look for life beyond the earth and to solve the mysteries of the universe.

Beyond 2020

And now what about beyond 2020; beyond our current thinking horizon. It is time to start thinking about this as we approach the New Millennium just three years away. Here is my vision:

If we find other planets out there, especially Earth-like planets, we will be faced with two strong imperatives: the first will be to find out a lot more about them than can be learned simply from the reflection spectrum; we will need to take the next and most difficult step of trying to image them for fine structural detail.

And second, there will be a strong imperative to find a way to travel there. This may sound a little far out, but just remember how far we have come. There are a lot of people who know with certainty what cannot be done. These are not the pioneers of the future.

We already know what it will take to image a planet around another star, and it is daunting . . . but not totally inconceivable.

And since we humans have this incredible drive to keep on exploring, we're going to want to send spacecraft toward these distant worlds we might have discovered in the cosmic ocean.

What an incredible way it would be to close the 21st century . . . to have a spacecraft approaching a rendezvous with another planetary system.

Our developments in autonomous, robust micro spacecraft are one of the keys to achieving that goal . . . but we need to extend them to the next level.

We'll also need to keep pushing on things like inflatable apertures and optical communications, so we can have a lightweight Hubble-size telescope to use as an optical transmitter on the spacecraft . . . and a Keck-size telescope for receiving signals on the ground. The key, however, is a revolutionary breakthrough in propulsion and power. We have begun the search.

We want to able to discover Earth-like planets around other stars . . . and then be able to get there with our robotic explorers in the span of just a few generations.

It will be extremely difficult . . . but also very rewarding. And the time to start considering the revolutionary technology for such missions is today.

The legacy for the 21st Century

We have set 25 year goals for ourselves that will transition us from the Century of Air Travel to the Century of Space Travel.

In the 19th Century we were citizens of Nationality. In the 20th Century we became citizens of a global interconnected economy. And in the 21st Century we will become citizens of the Solar System.

These are the kind of goals that we would like to bequeath to the 21st century. We want:

To be able to send an aquabot -- a submersible -- to explore the oceans under the ice of Europa . . . maybe we'll find some living organisms there . . . and in a broader sense, determine if life is unique to planet Earth;

to provide an image of the maelstrom at the event horizon of a black hole;

to image the continents and oceans on distant extra-solar planets;

and to send an exploratory mission to an Earth-like planet around a near-by star . . . first with robots.

We don't have the technology.

Yet.

And some might even say we never will.

But I ask you one final time to remember that meeting in San Antonio two years ago. You might recall that when I asked we develop an 8 meter, low cost, ultra-low weight, deployable mirror for the NGST . . . there were some who scoffed.

They said it's impossible.

Now we have at least two groups who say they can do it. You can see for yourself in the Exhibition Hall.

And in only two years.

In other words, it's OK to dream again at NASA and in America. And I encourage you to do just that.

Dream.

Because when we dream . . . America dreams . . . and the world dreams.

What drew me into this field . . . and one of the reasons why I'm so proud to be NASA Administrator . . . is that we -- especially the space science community -- are in the business of making dreams come true.

I hope that's why you're here. Now let's get to work.

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